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Special Report 77-17

THE EFFECTS OF LOW-PRESSURE WHEELED VEHICLES ON PLANT COMMUNITIES AND SOILS AT PRUDHOE BAY, ALASKA

D.A. Walker
P.J. Webber
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June 1977

CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
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An off-road vehicle test utilizing a smooth-tired Rolligon weighing approximately 25,000 lb. was conducted at Prudhoe Bay, Alaska, on 25 June 1976. Vehicle impact on the vegetation and terrain was documented at 32 stations selected as representative of the coastal tundra terrain. Twenty-seven stations were of single-pass track and five were multiple-pass lanes of up to 30 passes. The report documents the impacts with photographs and numerical ratings. Future observations will enable determination of rates of recovery.

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PREFACE

The 1976 field studies and report preparation were primarily supported by CRREL work unit Cold Regions Environmental Factors (DA Project 4A161102AT24, Task A2, Work Unit 002). The vegetation, soil and landform test site information was based on earlier studies sponsored by the Tundra Biome under National Science Foundation funding and the unrestricted grants to the University of Alaska from the Prudhoe Bay Environmental Subcommittee. The North Central District of the Alaska Department of Natural Resources provided a Land-Use Permit for the study. The cooperation of both BP Alaska, Inc., and Atlantic-Richfield Company in providing access to the site is greatly appreciated. The CATCO field office at Prudhoe Bay provided considerable assistance in executing the test reported upon. Dr. Charles W. Slaughter, formerly of CRREL, Fairbanks, and now with the Institute of Northern Forestry, assisted in organizing and executing the test.

CONTENTS

THE EFFECTS OF LOW-PRESSURE WHEELED VEHICLES ON PLANT COMMUNITIES AND SOILS AT PRUDHOE BAY, ALASKA

by

D. A. Walker[1], P. J. Webber[1], K. R. Everett[2], and J. Brown[3]

Introduction

One of the requirements of the oil exploration and development activities on the Arctic Coastal Plain of Alaska is transportation across wet tundra landscapes during the summer. Currently, this requirement is being met in the Prudhoe Bay area almost exclusively by the Rolligon, a low-pressure wide-wheeled vehicle engineered and developed by the Bechtel Corporation, and currently operated by Catco. Travel by Rolligons on the tundra is limited by state regulations. A permit must be obtained before traveling on the tundra.

The vehicle test reported here was designed to evaluate Rolligon impact on the various landscape types at Prudhoe and to place the common vegetation-microrelief combinations in broad categories of Rolligon impact sensitivity. The vegetation, soils, and landforms of most of the Prudhoe Bay oilfield have been mapped in detail (scale 1:6000) (Everett 1975, Webber and Walker 1975, Everett *et al.*, in prep.). The maps give a unique documentation of the vegetation in the oilfield as it existed in 1973. The information gained in the present study is to be used in the construction of a derived sensitivity map for summer off-road Rolligon traffic in the Prudhoe Bay area.

Tests investigating the impact of various types of summer off-road vehicles on tundra vegetation have been reported by several authors (Burt 1970a, 1970b, Radforth 1973a, 1973b, Rickard 1972, Sterrett 1976). As Rickard and Brown (1974) note in a review of current research on the effects of vehicles on arctic tundra, the results of these and other tests indicate a real need for standardization of tests for off-road vehicles. The rating scheme for evaluation of Rolligon impact used in our test should prove useful in other studies where vehicle impact is to be rated on a variety of well-known vegetation and landscape types.

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Description of the Test

The test was conducted on 25 June 1976, near the Putuligayuk River in an area where, on the basis of our mapping survey, it was possible to impact most of the common vegetation and terrain types in the Prudhoe Region. Permission for the tests was obtained by J. Brown and C. W. Slaughter from the State of Alaska, British Petroleum, and Atlantic Richfield Company. Participants were K. R. Everett, Ohio State University; D. A. Walker and J. Westley, University of Colorado; J. Brown and C. W. Slaughter, CRREL.

The vehicle used for the test was the smooth-tired Rolligon shown in Figure 1. The trailer contained a fuel tank half-full of diesel fuel to approximate a typical load. Total weight of the vehicle was approximately 25,000 lb. (11,340 kg). Tire pressure ranged from 3 to 5 p.s.i. The driver was instructed to travel at normal speeds, depending on terrain conditions.

The test occurred during a light rain. Condition of the tundra was generally very wet. Depth of thaw was shallow, ranging from 12 cm in some polygon troughs to about 28 cm on a small well-drained ridge. Maximum thaw of 38 cm was recorded in the center of a frost boil.

Figure 1. The test vehicle, a smooth-tired Rolligon weighing approximately 25,000 lbs.

Figure 2 is a map of the Prudhoe Bay area showing the location of the Rolligon test site. Figure 3 shows the Master Map (Everett et al., in prep.) of the site. The codes shown on the map represent the vegetation, soils and landforms within each map unit. A summary of the codes which were evaluated for impact is shown in Table 1.

The test consisted of two parts. The first part of the test was designed to evaluate impact to various landscape units after a single pass. A long course (approximately 3 km) was laid out to cross as many landscape units as possible. This course is shown as a dashed line on the map in Figure 2.

The second part of the test was designed to evaluate impact after 30 passes over three common landscape units occurring at Prudhoe Bay. The location of the three multiple-pass test lanes is shown in Figure 3 by the double solid lines.

Methods

During the test, 32 stations along the Rolligon track were selected as representative of the impact in various vegetation and terrain types. Twenty-seven of these stations were located along the single-pass track, and five were in the multiple-pass tracks. (Note circled numbers in Figure 3.) Photographs were taken of the Rolligon while traveling through the various landscape units. During the multiple-pass portion of the test, photos were taken of the test lanes after every five passes.

Four days after the test, the stations were revisited. This time impact was evaluated for the various vegetation types appearing in the master landscape codes, which describe the map units containing the stations. The rating scheme is described below. At some stations not all the vegetation codes appearing in the master landscape code were evaluated. This was usually due to the track crossing only a very small portion of a map unit and hence not impacting all the types appearing in the master landscape code. Depth of thaw was measured ten times outside the track for each subunit described. Also, photos were taken looking forward and backward along the track from each station.

The major feature of the rating scheme is that impact is broken into five categories which are rated separately. These categories were: 1) compression of the vegetation to the tundra surface, 2) compression of vegetation below a water surface, 3) displacement of individual plants, 4) breakage of plant parts, and 5) deposition or covering of the tundra due to displaced mud or plant material. Each of these categories can receive a score of up to 3 depending on the percentage of plants affected by the impact. An "overall immediate impact" score is also given. This value is subjective, but it is based on values in the other five categories.

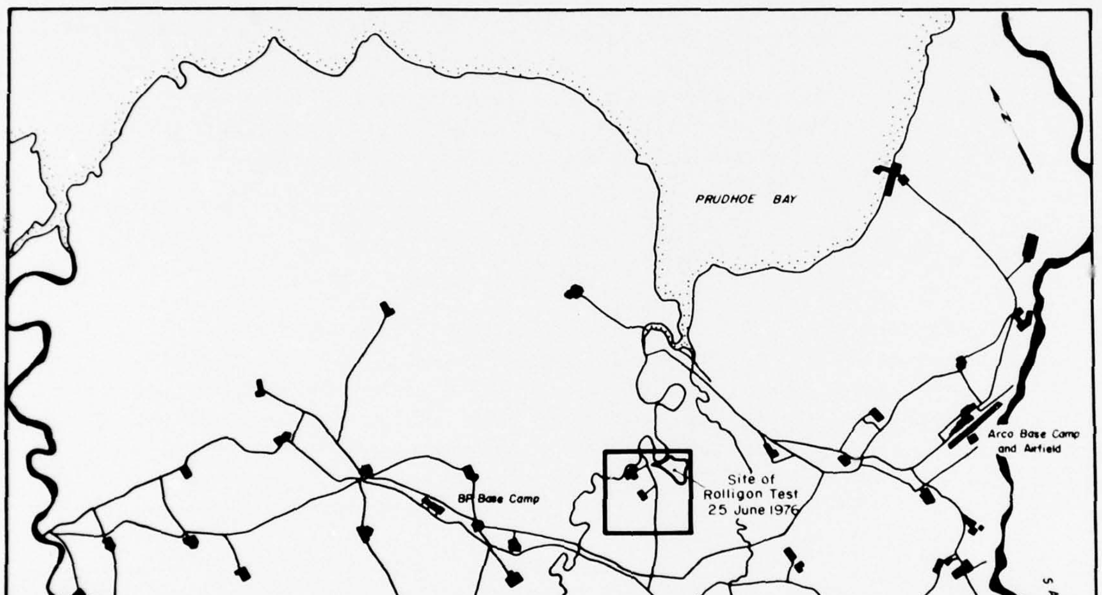

Figure 2. Location of Rolligon test site, Prudhoe Bay, Alaska, 25 June 1976. The solid rectangle shows the location of the map in Figure 3.

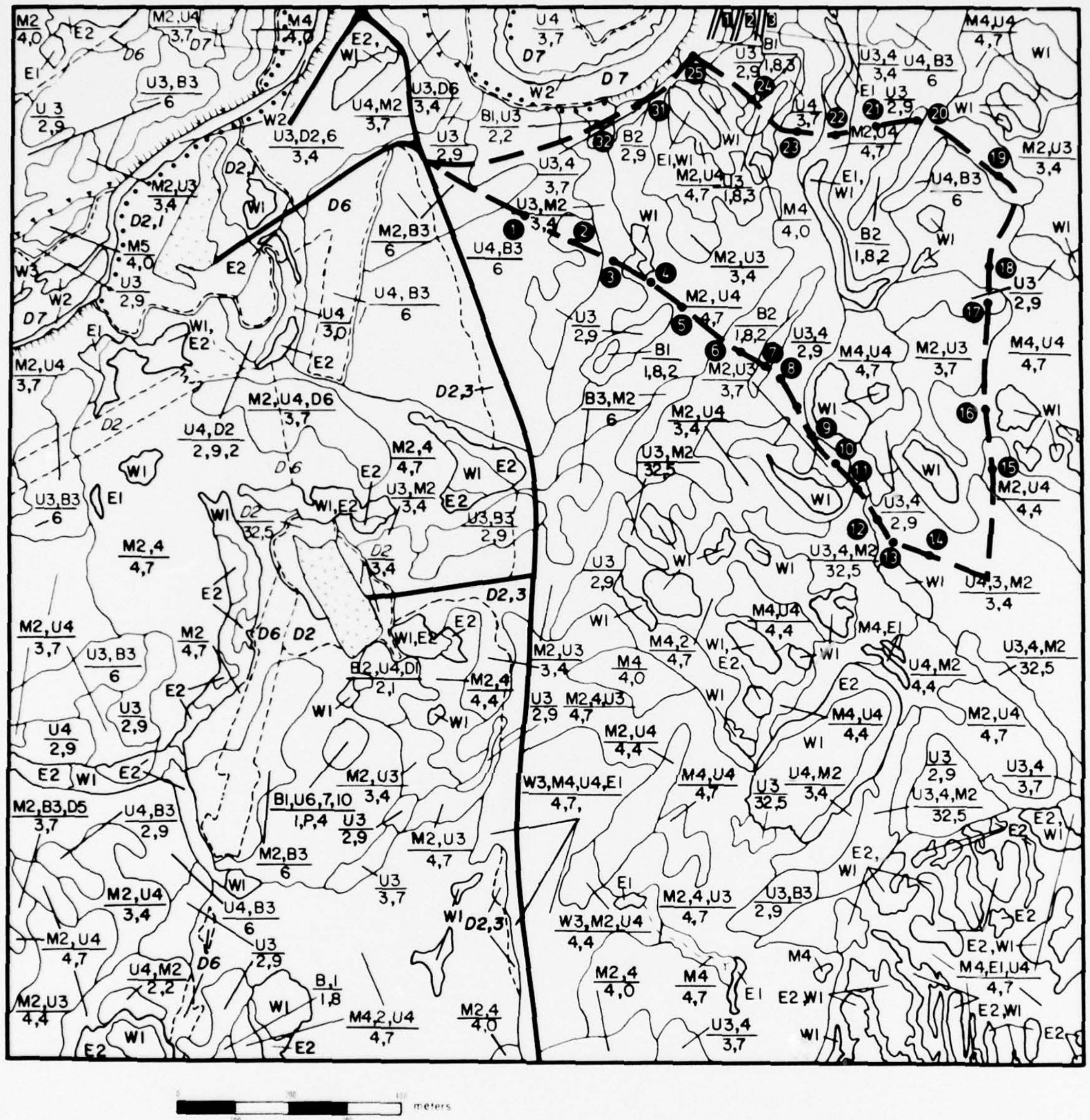

Figure 3. Master Map of the area in the vicinity of the Rolligon test. Dashed line shows the approximate location of the single pass track with the station numbers in black circles. The three multiple pass test lanes are shown by the double solid lines near the upper edge of the map. Keys to the landscape codes are given in Table 1. (From Everett et al., in press.)

Each of the five categories is also rated for predicted long-term impact (i.e., the impact which will be noticeable in one year). An "overall predicted long-term impact" score is also given. The rating scales are summarized in Table 2.

Figures 4-9 show examples of most of the common types of impact.

Table 1. Summary and key to numbers appearing in the landscape codes in Figure 3. (From Everett et al., in preparation.)

Vegetation Codes (numerator)

Code	Characteristic Species	Characteristic Microsite
B1	*Dryas integrifolia, Oxytropis nigrescens, Carex rupestris, Distichium capillaceum, Lecanora epibryon*	Pingos, elevated ridges, edges of river bluffs
B2	*Dryas integrifolia, Saxifraga oppositifolia, Salix reticulata, Ditrichum flexicaule, Lecanora epibryon*	Pingos, high-center polygons
B3	*Dryas integrifolia, Eriophorum angustifolium, Saxifraga oppositifolia, Bryum wrightii, Thamnolia* spp.	Frost boils
U3	*Dryas integrifolia, Eriophorum triste, Carex bigelowii, Carex aquatilis, Tomenthypnum nitens, Thamnolia* spp.	Well-drained upland sites, polygon rims, aligned hummocks
U4	*Carex aquatilis, Eriophorum triste, Dryas integrifolia, Salix reticulata, Salix arctica, Tomenthypnum nitens*	Moister upland sites, polygon rims, aligned hummocks, some low polygon centers
M2	*Carex aquatilis, Eriophorum angustifolium, Pedicularis sudetica, Drepanocladus brevifolious, Cinclidium latifolium*	Low moist sites, low polygon centers and troughs, lake margins
M4	*Carex aquatilis, Carex saxatilis, Scorpidium scorpioides*	Low wet sites, low polygon centers, lake margins

Soil Codes (1st number in denominator)

1	Pergelic Cryoboroll
2	Pergelic Cryaquoll
3	Histic Pergelic Cryaquept--Pergelic Cryohemist complex
32	Mixed--mainly types 3 and 2
4	Histic Pergelic Cryaquept--Pergelic Cryof rist complex
6	Frost boil tundra with Ruptic Histic Pergelic Cryaque, - soil in the frost boils

Landform Codes (2nd number in the denominator)

2	High center polygons, center-trough contrast less than or equal to 0.5 m
4	Low center polygons, rim-center contrast less than or equal to 0.5 m
5	Mixed--including both high center and low center in intricate pattern
6	Frost boil tundra (non-sorted)
7	Strangmoor and/or large diameter, commonly discontinuous low center polygon pattern; little or no microrelief contrast
8	Earth hummocks associated with dissected slopes
9	Reticulate--slightly convex polygons with hummocky microrelief; hummock-interhummock relief contrast less than or equal to 15 cm

Slope Codes (3rd number in the denominator)

Code	Slope Range
No code	0-2%
2	2-6%
3	6-12%

Water Codes

W1	Lake
W2	River
W3	Flooded area due to road

Table 2. Rating Scheme for Evaluation of Rolligon Impact - Each factor is rated according to immediate impact (numerator) and predicted long term impact (denominator).

Impact Categories

Compression to tundra surface - refers to the permanent bending and compressing of live and standing dead vegetation to the tundra surface so that it becomes flattened and oriented to the direction of travel.

0 - no observable compression vegetation to tundra surface.

1 - slight compression of vegetation (1-10% of plants affected).

2 - moderate compression of vegetation (10-50% of plants affected).

3 - severe compression of vegetation (> 50% of plants affected).

Compression below water surface - refers to the compression of sedges and moss hummocks below a water surface.

0 - no water or no observable compression of vegetation below water surface.

1 - slight compression of vegetation below water surface (1-10% of plants affected).

2 - moderate compression of vegetation below water surface (10-50% of plants affected).

3 - severe compression of vegetation below water surface (> 50% of plants affected).

Displacement - refers to several categories of disturbance.

a) tussocks of moss or Eriophorum vaginatum moved or overturned.

b) displacement of wet mosses such as Scorpidium scorpioides and Drepanocladus brevifolious by splashing action.

c) exposure of bare soil by removal of vegetation mat.

0 - no displacement of vegetation.

1 - some displacement of vegetation (1-10% of plants affected).

2 - moderate displacement of vegetation (10-50% of plants affected).

3 - severe displacement of vegetation (> 50% of plants affected).

Breakage - refers to breakage of plant stems or flowering stalks.

0 - no breakage observed

1 - some breakage observed (1-10% of plants affected).

2 - moderate breakage observed (10-50% of plants affected).

3 - severe breakage observed (> 50% of plants affected).

Deposition - refers to accumulation of mud and moss to sides of track.

0 - no mud or moss accumulation at sides of track.

1 - few shallow patches of mud or moss.

2 - many shallow patches of mud or moss.

3 - continuous thick deposit of mud or moss.

Overall Immediate Impact

Rated subjectively on the basis of immediate impact scores in the five categories above: 0 - no impact; 1 - slight impact; 2 - moderate impact; 3 - severe impact.

Impact in One Year

Rated subjectively on the basis of long-term impact scores in the five categories above. The scale is the same as for overall immediate impact.

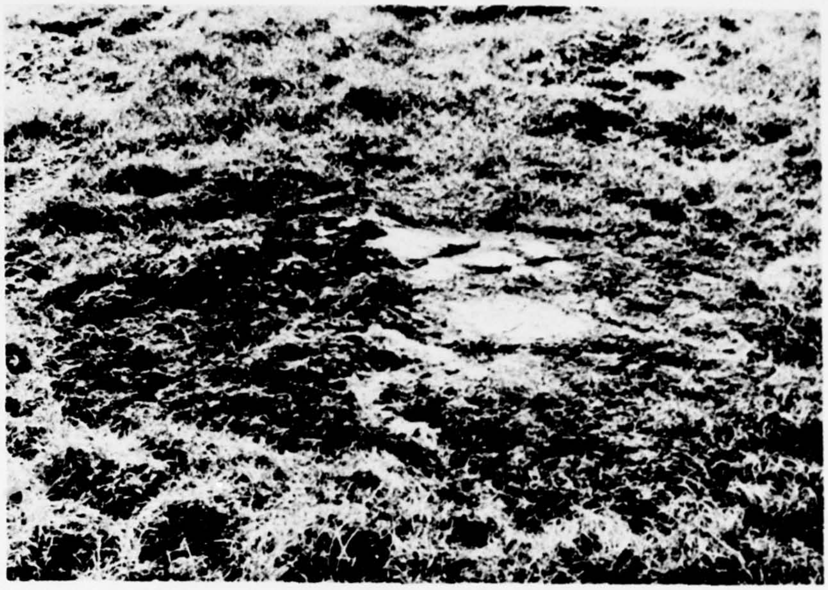

Figure 4. Example of compression to tundra surface. Tires compressed the vegetation on the right side of the frost boil.

Figure 5. Another example of compression to tundra surface. Note orientation of vegetation to direction of travel.

Figure 6. Example of compression of vegetation below a water surface.

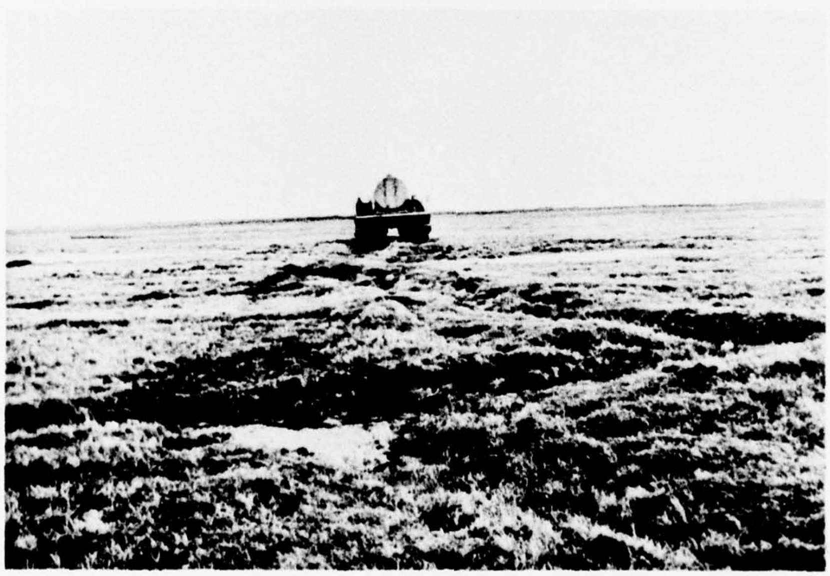

Figure 7. Example of displacement impact. Two types of displacement occurred at this site; 1) moss was displaced from the trough to the polygon rim, and 2) some of the vegetation mat on the polygon rim was removed.

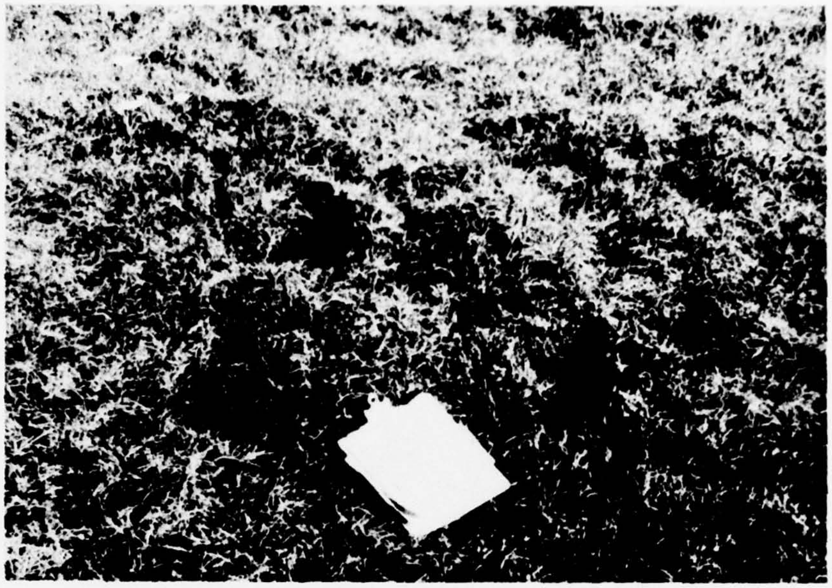

Figure 8. Close up of two small areas where the vegetation mat was removed due to the scuffing action of the Rolligon tires. This minor damage sometimes occurred on polygon rims.

Figure 9. Example of deposition of mosses to sides of the Rolligon track. The figure also clearly shows the compression of sedges and moss hummocks below the water surface.

Results

Single Pass Rolligon Track

Photographs taken at the stations are presented in Appendix A. The impact scores for each station are shown in Table 3. The table also gives depth of thaw in each subunit. The various vegetation microsite combinations can be ordered in terms of their impact scores by finding the mean scores for each vegetation-microsite combination. This has been done in Table 4. The Table is arranged with the lowest mean Overall Immediate Impact score at the top and the highest score at the bottom.

Figures 10 to 13 show impact in some of the common vegetation-microsite combinations along the route of the single pass Rolligon track. Areas which were most heavily impacted were those with a combination of wet vegetation stand types and pronounced microrelief features, such as wet polygon troughs, or wet meadows with closely spaced aligned hummocks. Figure 14 shows the Rolligon crossing a wet polygon trough with the consequent splashing of water and vegetation to the sides. Figure 15 shows a polygon trough after impact, with displacement of the mosses from the trough, and damage to the polygon rim. Figure 16 shows a wet area with closely spaced aligned hummocks (Station 22), which received moderate impact even though the Rolligon travelled very slowly through this area.

Thirty Pass Rolligon Test Lanes

Impact in the thirty pass test lanes was considerably greater than along the single pass track. Figures 17, 19, and 21 show the test lanes immediately after 30 passes in each lane. Figures 18, 20, and 22 show the lanes four days after the tests. The lanes were rated for impact in the same manner as the stations along the single pass track. The impact scores are shown in Table 5.

Discussion and Conclusions

Single Pass Rolligon Track

It is evident that vegetation <u>and</u> microrelief should be considered in the evaluation of impact caused by Rolligons in the Prudhoe area. The results shown in Table 5 give a means of rating the various vegetation-microsite combinations for predicted impact caused by a single pass. Some combinations occurred only once or twice, and it may be that more observations would alter the order of the combinations in the table. However, the general trend is apparent. Dry sites with little microrelief were lightly impacted, while wet areas, particularly those with pronounced microrelief, were more heavily impacted.

The types of damage to the different vegetation-microsite combinations can be summarized as follows:

<u>Compression to tundra surface</u>. Some compression of vegetation and microrelief occurred in nearly all vegetation-microsite combinations. (The single exception was the one occurrence of a map unit with Type U3 troughs.) Most noticeable compression occurred in frost boils, which were very wet at the time of the test.

Table 3. Impact scores for twenty-seven stations along the single pass Rolligon track, June 25, 1976. Each station is rated for the one to three vegetation subunits appearing in the numerator of the landscape codes. The five impact categories are rated for immediate impact (numerator) and predicted impact in one year (denominator). Each subunit is also given an overall immediate impact score, based on the scores in the five impact categories, and a score for predicted impact in one year.

Station	Landscape Code	Characterization	Subunit	Impact Categories: Compression to Tundra Surface	Impact Categories: Compression Below Water Surface	Impact Categories: Displacement	Impact Categories: Breakage	Impact Categories: Deposition of Moss or Mud	Overall Impact: Immediate Impact	Overall Impact: Predicted Impact in One Year	Depth of Thaw (cm) 6/29/76
1	$\frac{\text{U4, B3}}{\text{6}}$	Frost boil tundra	B3 Frost Boil	3/2	0/0	2/1	0/0	0/0	2	2	38.1
			U4 Upland Tundra	1/1	1/1	0/0	0/0	0/0	1	1	25.8
2	$\frac{\text{U3}}{\text{2, 9}}$	Mesic tundra	U3 Upland	1/1	0/0	1/1	0/0	0/0	1	1	15.1
3	$\frac{\text{U3, M2}}{\text{3, 4}}$	Dry & moist low center polygons	M2 Low Center	1/1	0/0	1/1	0/0	0/0	1	1	15.5
			U3 Rim	2/1	0/0	2/2	1/1	0/0	2	1	17.6
			M2 Trough	2/1	2/2	1/1	0/0	2/1	2	1	16.3
4	$\frac{\text{M2, U4}}{\text{4, 7}}$	Moist area with intermittent polygons	M2 Low Center	2/1	1/1	2/2	0/0	2/2	2	1	15.6
			U4 Rim	1/1	1/0	2/2	1/1	1/0	2	2	12.6
			M4 Trough	1/1	3/1	2/1	0/0	2/1	2	2	12.0
5	$\frac{\text{U3, 4}}{\text{2, 9}}$	Mesic tundra, lower slope of small ridge	U3 Upland	1/1	0/0	0/0	0/0	0/0	1	0	14.2
6	$\frac{\text{B1, B2}}{\text{1, 8, 2}}$	Barren tundra, crest of small ridge	B1 Ridge	1/1	0/0	0/0	1/1	0/0	1	1	23.6
7	$\frac{\text{U3, 4}}{\text{2, 9}}$	Mesic tundra, lower slope of small ridge	U3 Upland	1/1	0/0	0/0	0/0	0/0	1	0	16.4
8	$\frac{\text{U3, 4}}{\text{2, 9}}$	Mesic tundra	U3 Upland Tundra	1/0	0/0	1/0	0/0	0/0	1	0	12.9

Table 3. (continued)

Station	Landscape Code	Characterization	Subunit	Impact Categories: Compression to Tundra Surface	Compression Below Water Surface	Displacement	Breakage	Deposition of Moss or Mud	Overall Impact: Immediate Impact	Predicted Impact in One Year	Depth of Thaw (cm) 6/29/76
9	$\frac{M4,\ U4}{4,\ 7}$	Wet area, intermittent polygons	M4 Trough	1/1	3/2	2/2	2/0	2/2	3	2	-
10	$\frac{M2,\ U3}{3,\ 7}$	Moist area with intermittent polygon rims	M2 Low Center	2/1	1/1	1/1	0/0	1/0	1	1	12.9
			U3 Rim	1/1	0/0	1/0	1/0	0/0	1	1	-
			M2 Trough	1/1	2/2	1/1	0/0	1/0	1	1	-
11	$\frac{U3,\ 4,\ M2}{32,\ 5}$	Mixed high and low center polygons	U3 Center	1/1	0/0	0/0	0/0	0/0	1	0	13.5
			M2 Trough	2/1	1/0	0/0	0/0	0/0	2	1	14.7
12	$\frac{U4,\ 3,\ M2}{3,\ 4}$	Moist low center polygons	M2 Low Center	1/1	2/2	2/2	0/0	2/2	1	0	13.4
			U3 Rim	2/2	0/0	1/1	1/1	0/0	2	1	13.3
			M4 Trough	1/1	2/2	1/1	0/0	2/2	2	1	12.6
13	$\frac{U3}{2,\ 9}$	Mesic tundra	U3 Upland	1/0	0/0	0/0	0/0	0/0	1	0	12.4
14	$\frac{U4,\ 3,\ M2}{3,\ 4}$	Dry low center polygons	U4 Low Center	1/1	0/0	0/0	0/0	0/0	1	1	16.0
			U3 Rim	1/1	0/0	1/1	0/0	0/0	1	0	12.3
			M2 Trough	2/1	2/2	2/2	0/0	1/1	2	2	13.9
15	$\frac{M2,\ U4}{4,\ 4}$	Wet low center polygons	M2 Low Center	2/1	1/1	1/1	0/0	2/2	2	2	21.3
			U4 Rim	1/1	0/0	1/0	0/0	1/1	2	1	14.7
			M4 Trough	1/1	2/2	2/1	0/0	1/1	2	2	17.7

Table 3. (continued)

Station	Landscape Code	Characterization	Subunit	Impact Categories: Compression to Tundra Surface	Impact Categories: Compression Below Water Surface	Impact Categories: Displacement	Impact Categories: Breakage	Impact Categories: Deposition of Moss or Mud	Overall Impact: Immediate Impact	Overall Impact: Predicted Impact in One Year	Depth of Thaw (cm) 6/29/76
16	M4, U4 / 4, 7	Wet area with aligned hummocks	M4 Low Area	2/1	3/2	2/2	0/0	2/2	2	2	19.8
			U4 Hummock	1/0	0/0	1/0	0/0	1/0	1	1	16.8
17	U3 / 2, 9	Mesic tundra	U3 Upland	1/0	0/0	0/0	0/0	0/0	1	0	13.7
18	M4, U4 / 4, 7	Wet area with aligned hummocks	M4 Low Area	2/1	2/2	2/2	0/0	2/2	2	2	22.1
			U4 Hummock	1/1	0/0	1/1	0/0	1/0	1	1	-
19	U3 / 2, 9	Mesic tundra	U3 Upland	1/0	0/0	0/0	0/0	0/0	1	0	10.3
20	B2 / 1, 8, 2	Small ridge, crest	B2 *Ridge*	1/0	0/0	0/0	0/0	0/0	0	0	16.9
21	U3 / 2, 7	Mesic tundra	U3 Upland	1/0	0/0	0/0	0/0	0/0	1	0	12.8
22	M2, U4 / 4, 7	Wet area with aligned hummocks	M2 Low Area	2/1	1/1	2/1	0/0	2/1	2	2	17.1
			U4 Hummock	1/0	0/0	1/0	0/0	2/1	2	1	20.0
23	U3 / 2, 9	Mesic tundra	U3 Hummock	1/0	0/0	0/0	0/0	0/0	1	0	13.2
24	U3 / 2, 9	Mesic tundra	U3 Upland	1/0	0/0	1/1	0/0	0/0	1	0	15.5
25	B1 / 1, 8, 3	Small ridge, crest	B1 Ridge	1/1	0/0	1/1	1/0	0/0	1	1	27.5
26-30	Multiple Pass Test Lanes, See Table 5.										
31	U3, 4 / 3, 7	Mesic area with aligned hummocks	U3 *Flat Area*	1/0	0/0	0/0	0/0	0/0	1	0	16.9
			U4 Trough	1/0	0/0	1/0	1/0	0/0	1	1	-
32	B1, U3 / 2, 2	High center polygons	B1 High Center	1/0	0/0	1/1	1/0	0/0	1	0	22.2
			U3 Trough	0/0	0/0	0/0	0/0	0/0	0	0	-

Table 4. Mean impact scores for the Rolligon Test, June 25, 1976. List is arranged in order from the lowest overall immediate impact score to the highest.

Vegetation Type	No. of Occurences	IMPACT SCORES: Impact Catagories					IMPACT SCORES: Overall Impact	
		Compression to Tundra Surface	Compression Below Water Surface	Displacement	Breakage	Deposition	Immediate	Long Term
U3 Trough	1	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00	0.00
B2 Ridge	1	1.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00	0.00
U3 Center	2	1.00/0.50	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	1.00	0.00
U3 Upland	10	1.00/0.30	0.00/0.00	0.30/0.50	0.00/0.00	0.00/0.00	1.00	0.00
B1 Ridge High Center	3	1.00/0.67	0.00/0.00	1.00/1.00	1.00/0.33	0.00/0.00	1.00	0.67
U4 Center	1	1.00/1.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	1.00	1.00
U4 Upland	1	1.00/1.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	1.00	1.00
U4 Trough	1	1.00/0.00	0.00/0.00	1.00/0.00	1.00/0.00	0.00/0.00	1.00	1.00
U3 Rim	4	1.50/1.25	0.00/0.00	1.25/1.00	0.75/0.50	0.00/0.-0	1.50	0.75
M2 Low center or level area	6	1.67/1.00	1.00/1.00	1.50/1.33	0.00/0.00	1.50/1.17	1.50	1.67
U4 Rim or Hummock	5	1.00/0.60	0.20/0.00	1.20/0.60	0.20/0.20	1.20/0.40	1.00	1.20
M2 Trough	4	1.75/1.00	1.75/1.50	1.25/1.00	0.00/0.00	1.00/0.50	1.75	1.25
B3 Frost Boil	1	3.00/1.00	0.00/0.00	2.00/1.00	0.00/0.00	0.00/0.00	2.00	2.00
M4 Low center or level area	2	2.00/1.00	2.50/2.00	2.00/2.00	0.00/0.00	2.00/2.00	2.00	2.00
M4 Trough	4	1.00/1.00	2.00/1.75	1.75/1.25	0.50/0.00	2.00/1.75	2.25	1.75

Figure 10. Rolligon track in Type B2 vegetation after a single pass. Vegetation in the middle background is Type U3. Dark area in the far background is Type M4.

Figure 11. Rolligon impact in Type U3 after a single pass.

Figure 12. Rolligon impact after a single pass to Type U4 (foreground) and Type M2.

Figure 13. Rolligon impact in Type M4 after a single pass.

Figure 14. Rolligon crossing a wet polygon trough.

Figure 15. Polygon trough and damaged polygon rim four days after the test.

Figure 16. Impact in a wet area (Vegetation Type M4) with closely spaced aligned hummocks (Vegetation Type U4) after a single pass.

Figure 17. Multiple Pass Test Lane No. 1 immediately after 30 passes. Vegetation is Type B1.

Figure 18. Lane No. 1 four days after test.

Figure 19. Multiple Pass Test Lane No. 2 immediately after 30 passes. Vegetation is Type U3.

Figure 20. Lane No. 2 four days after test.

Figure 21. Multiple Pass Test Lane No. 3 immediately after 30 passes. Vegetation in wettest areas Type M2. Hummocks are Type U4.

Figure 22. Lane No. 3 four days after test. Note the lighter soil in the track showing locations of several frost boils.

Table 5. Rolligon Impact on Vegetation - Thirty Passes, June 25, 1976.

Lane	Map Unit Code	Characterization	Subunit	Compression to Tundra Surface	Compression Below Water Surface	Displacement	Breakage	Deposition	Overall Immediate Impact	Long-Term Impact
1	B1 / 1, 8, 3	Barren tundra, crest of small ridge	B1 Small Ridge Top	2/2	0/0	2/2	1/0	0/0	2	2
2	U3 / 2, 9	Dry tundra	U3 Upland	3/1	0/0	1/1	1/0	0/0	2	1
3	U4, 3 / 3, 4	Moist low center polygon	M2 Center	3/3	0/0	2/2	2/2	3/3	3	2
			U3 Rim	3/3	0/0	2/2	2/2	3/2	3	2
			B3 Frost Boil	3/3	0/0	3/3	2/2	3/3	3	3

Moderate compression occurred in Type M4 and M2 meadows, low polygon centers, and troughs, and on Type U3 rims. Minor compression occurred in the other categories. During the test, sedge vegetation in general was bent and oriented to the direction of travel. Sedges in wet sites tended to remain prostrate, while sedges in drier sites tended to spring back. In communities of mat dicots and cushion plants the effect of one pass was almost unnoticeable. However, small earth hummocks containing crust lichens and other vegetation showed some minor signs of compression.

Compression below a water surface. This type of damage was noticeable as a definite decrease in the number of plants and moss hummocks sticking above the water inside the Rolligon wheel marks compared to similar areas outside the tracks. Vegetation Type M4 showed very noticeable compression of vegetation below the water surface. Type M2 showed moderate impact in this category. This type of damage is expected to be still very noticeable in one year.

Displacement. In the wet areas (Vegetation Types M2 and M4) the main type of damage in this category was displacement of mosses caused by splashing action and the clinging of wet mosses to the flat Rolligon tires. This impact will still be quite noticeable in one year.

In drier areas the main type of displacement was the removal of small patches of the vegetation mat caused by scuffing action of the Rolligon tires. This sometimes occurred on polygon rims.

Breakage. Breakage of plant parts was not seen to be a major problem in any of the areas impacted, but this could change later in the summer with the development of flowering stems and culms.

Deposition of vegetation or mud to the sides of the Rolligon track. Again this was a problem mainly in the wet areas (Vegetation Types M2 and M4). It also occurred on some polygon rims next to wet troughs where material from the trough was splashed. This type of impact appears to be fairly persistent although the underlying sedges will eventually grow up through the deposit.

The various vegetation-microsite combinations can be divided into three relative sensitivity groups (Table 6) on the basis of their mean overall immediate impact scores: 1) those with scores less than or equal to 1.00 (low sensitivity to Rolligon impact), 2) those with scores between 1.00 and 2.00 (moderate sensitivity), and 3) those with scores greater than or equal to 2.00 (high sensitivity).

On the basis of these categories, it is possible to construct a terrain sensitivity map using the master map (Figure 2) as a base. A portion of the final map is shown in Figure 23.

Table 6. Relative sensitivity of various vegetation-microrelief categories to a single Rolligon pass, Prudhoe Bay, Alaska.

Low sensitivity vegetation-microsite combinations	Moderate sensitivity vegetation-microsite combinations	High sensitivity vegetation-microsite combinations
U3 Trough	U3 Rim	B3 Frost boil
B2 Ridge	M2 Low center or flat area	M4 Low center or flat area
U3 Low center	U4 Rim or hummock	M4 Trough
U3 Upland	M2 Trough	
B1 Ridge or high center		
U4 Low center		
U4 Upland		
U4 Trough		

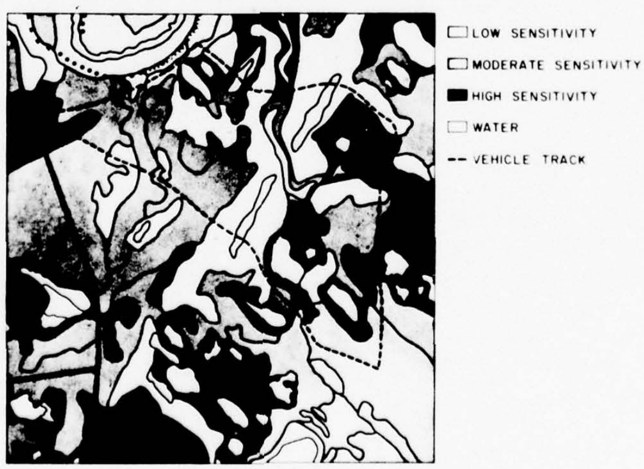

Figure 23. Terrain sensitivity to one Rolligon pass based on results of test 25 June 1976. (From Everett et al., in press.)

Multiple Pass Test Lanes

All three of the test lanes were heavily impacted by the Rolligon, which indicates that none of the common vegetation types at Prudhoe will hold up under thirty passes when the terrain is wet.

Lane 1 was located on a small dry ridge with sparse vegetation consisting mainly of cushion and mat dicots with crustose and fruticose lichens. The Rolligon flattened the microrelief considerably, and in many places left the surface completely bare. This happened particularly on the outside downhill edge of a long radius turn which the Rolligon made. Recovery in this lane will probably be slow due to the sparse vegetation and the exposed microsite.

Lane 2 was located on a well drained site with dry sedge tundra. The main effect of the Rolligon was flattening of the microrelief. A few patches of bare earth were exposed, but the initial good coverage of vegetation and the fact that most of the sedges can readily reestablish themselves through vegetative propagation will probably lead to relatively rapid recovery.

Lane 3 was located in an area of moist low-center polygons. Vegetation consisted of sedges and mosses in the polygon centers. Dry tundra occurred on the polygon rims. There were also several frost boils in this lane. Impact from the Rolligon was most severe at the frost boils and at the polygon rims where microrelief was flattened or depressed considerably. Bare peat was exposed in several places, and mud was displaced to the sides in thick deposits. Recovery will probably be fairly good in areas where the bare soil was not exposed. In the deeply rutted areas recovery will be much slower.

By the end of July Lane 3 was completely dry; so this site must be considered at the dry end of the spectrum of the moist-to-wet vegetation types. Thermokarst of polygon troughs may eventually occur, but the relative dryness of the site makes this possibility uncertain. In wetter areas thermokarst in the polygon troughs would certainly occur after a similar test.

Evaluation of the Rating Scheme

The rating system was fairly effective for the purpose of this study, which was to place the various vegetation types in broad categories of impact susceptibility. An attempt was made to objectively rate impact by breaking the disturbance into several categories and estimating the percentage of plants affected by each category. The values for "overall immediate impact" and "predicted impact in one year" were based on the scores in the five impact categories. These "overall" values, however, were subjective, and different judges would undoubtedly arrive at different scores. It would be desirable to arrive at the "overall" impact value by some objective means. Adding all the scores in the five impact categories would be one such means, but this would automatically weight all aspects of the impact equally. Any mathematical combining of the scores is going to have similar problems. The impact from a single pass of a Rolligon is primarily an esthetic impact, and any system developed for measuring this is going to have subjectivity inherent in it.

Adequate quantitative studies of impact will require long-term programs of testing vehicles in a wide variety of vegetation and terrain conditions. The programs should consider the effects of factors such as depth of thaw, soil moisture, payload, velocity of the Rolligon, and various turning radii. The problem of how to give some value to the impact which the eye sees is a difficult one. Measuring leaf area index and albedo are two approaches to this problem but require either a great deal of time or expensive instruments. Data gathered in long-term testing programs may eventually lead to reliable models for predicting impact, but meanwhile it will be necessary to rely on qualitative assessments of impact which are based on familiarity with the vegetation and terrain.

Summary

On 25 June 1976, a Rolligon test was conducted to evaluate Rolligon impact on the common vegetation and microsite combinations at Prudhoe Bay, Alaska. The test utilized an impact rating scheme which divided impact into five categories: 1) compression of vegetation to tundra surface, 2) compression below a water surface, 3) displacement, 4) breakage, and 5) deposition.

These categories were rated for immediate impact and predicted impact in one year. The purpose of the test was to place the various vegetation-microsite combinations into three broad impact sensitivity classes. The test consisted of two phases: 1) a three km single pass track, and 2) three 30 pass test lanes. Impact in the single pass track was greatest in the wet sites with pronounced microrelief features. Upland sites received very minor impact. In the multiple pass lanes, the dry exposed site and the moist site received heavy impact. Impact was least in the lane containing dry upland sedge tundra.

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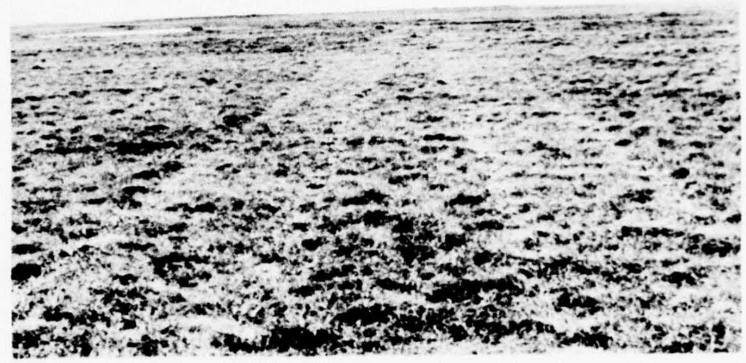
APPENDIX A

Photographs taken four days after the Rolligon test of terrain at each station. Refer to Table 3 for impact ratings at each station.

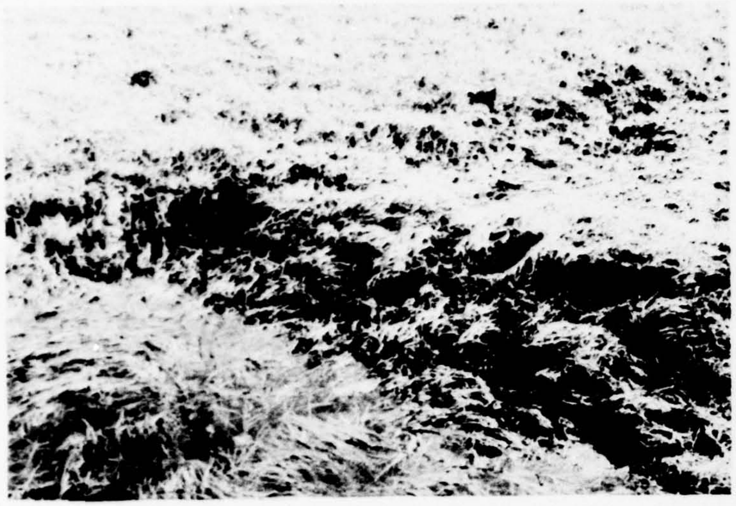
Station 1, looking forward. Map code $\frac{\text{U4, B3}}{6}$



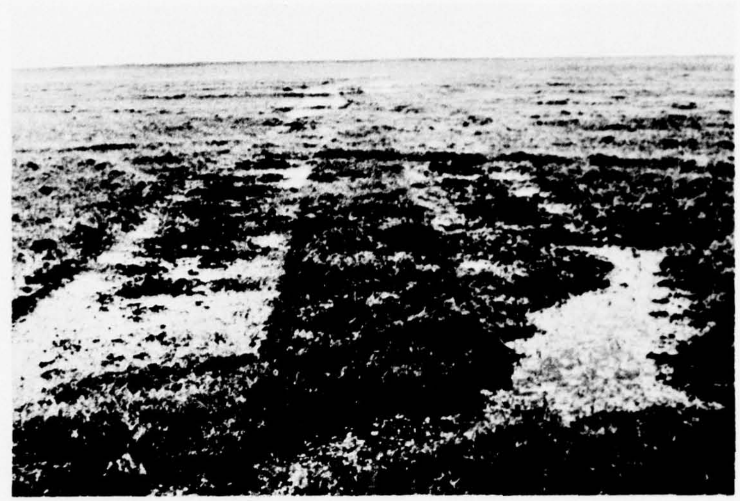
Station 2, looking forward. Map code $\frac{\text{U3}}{2,\ 9}$

Station 1, looking back. Note impacted frost boil.

Station 2, looking back.



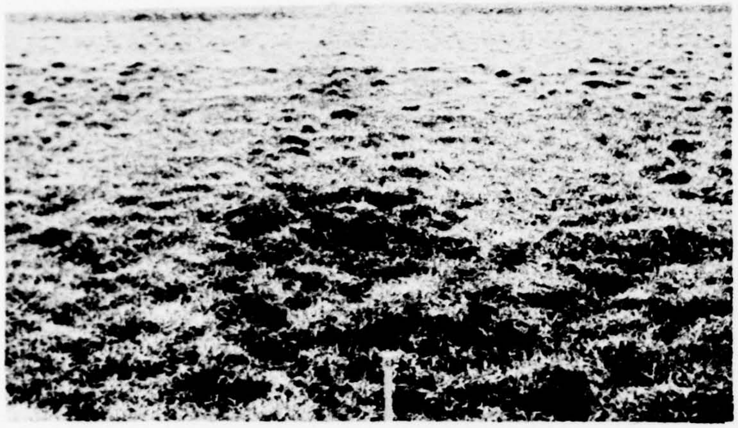
Station 3, impacted trough from side.
Trough is Type M4.



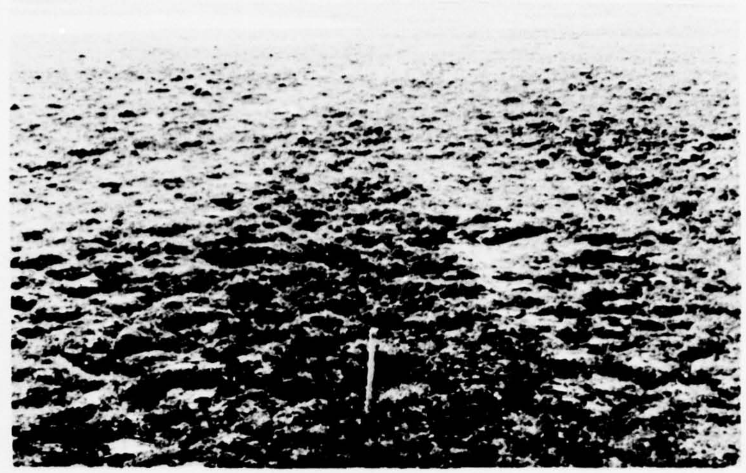
Station 4, looking forward. Map code $\frac{M2,\ U4}{4,\ 7}$

Station 3, looking forward. Map code $\frac{U3,\ M2}{3,\ 4}$

Station 4, looking back.

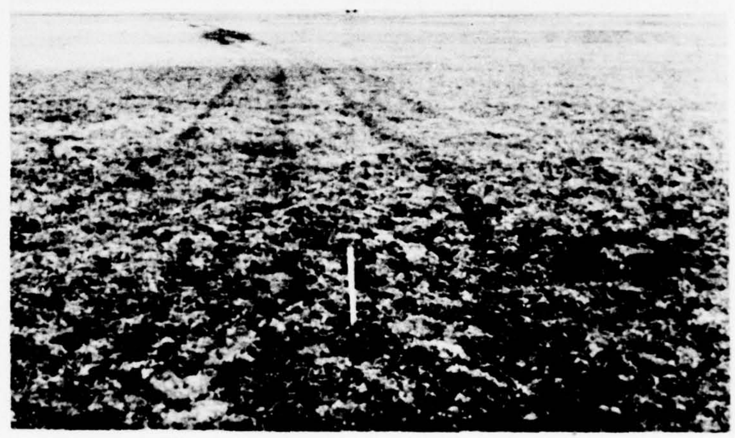


Station 5, looking forward. Map code $\frac{U3}{2,\ 9}$



Station 6, looking forward. Map code $\frac{B1}{1,\ 8,\ 2}$

Station 5, looking back.

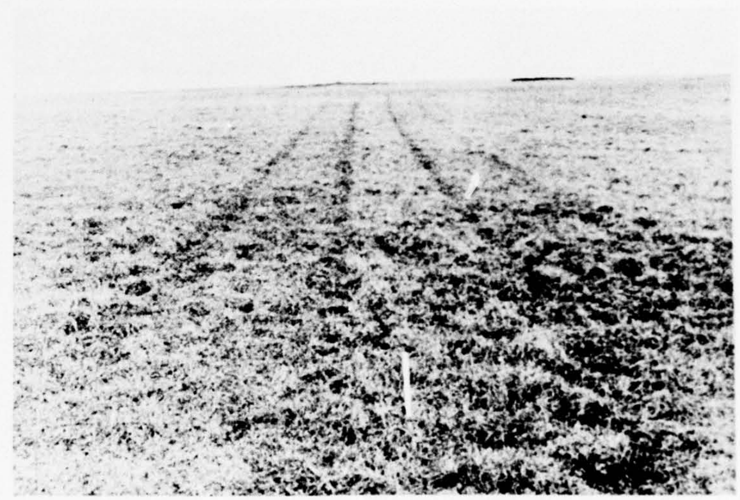


Station 6, looking back.

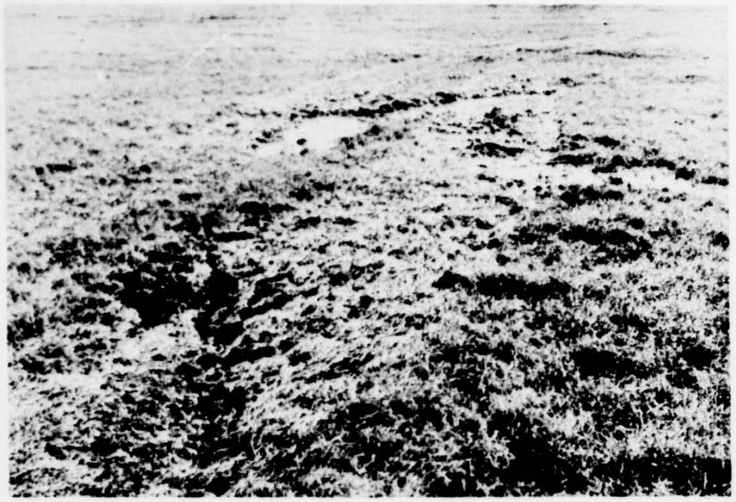
Station 7, looking forward. Map code $\frac{\text{U3, 4}}{\text{2, 9}}$

Station 8, looking forward. Map code $\frac{\text{U3, 4}}{\text{2, 9}}$

Station 7, looking back.



Station 8, looking back



Station 9, impacted polygon trough.

Station 10, looking forward. Map Code $\frac{\text{M2, U3}}{\text{3, 7}}$

Unit is very small and not a good example of this type.

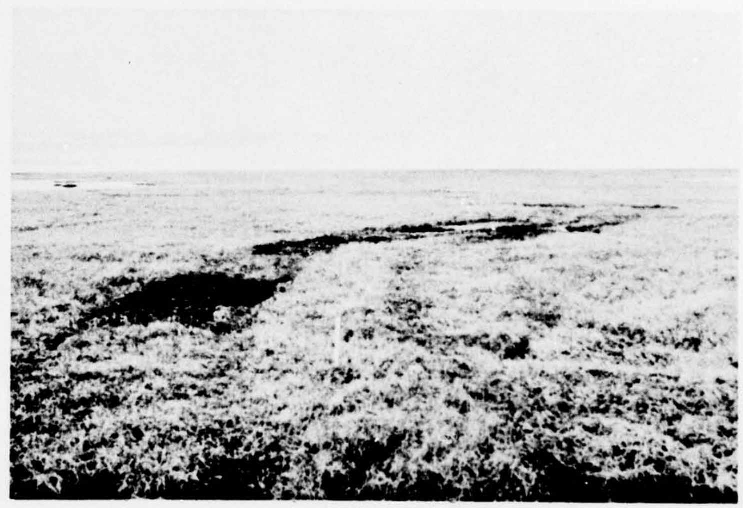
Station 9, looking back. Note: Main part of unit is classified $\frac{\text{M4, U4}}{\text{4, 7}}$; Rolligon went around unit due to excessive moisture.)

Station 10, looking back.

Station 11, looking forward. Map code $\frac{\text{U3, 4, M2}}{\text{32, 5}}$

Station 12, looking forward. Map code $\frac{\text{U4, 3, M2}}{\text{3, 4}}$

Station 11, looking back.

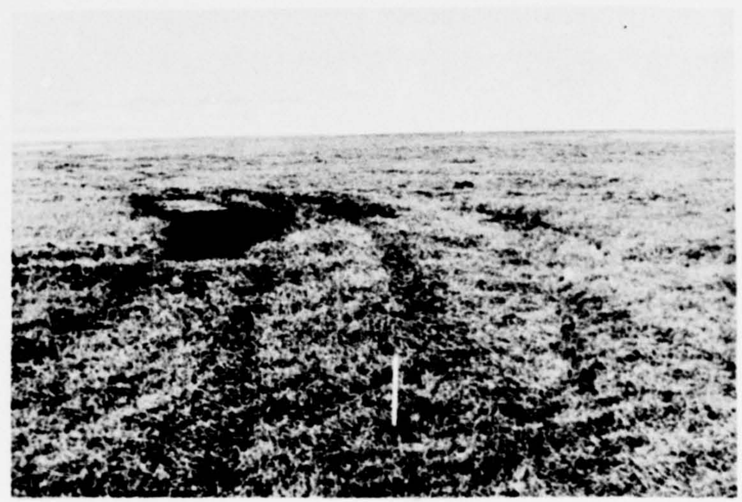


Station 12, looking back.

Station 13, looking forward. Map code $\frac{U3}{2,\ 9}$

Station 14, looking forward. Map code $\frac{U4,\ 3,\ M2}{3,\ 4}$

Station 13, looking back. The $\frac{U4,\ 3,\ M2}{3,\ 4}$ unit is in the background.



Station 14, looking back.

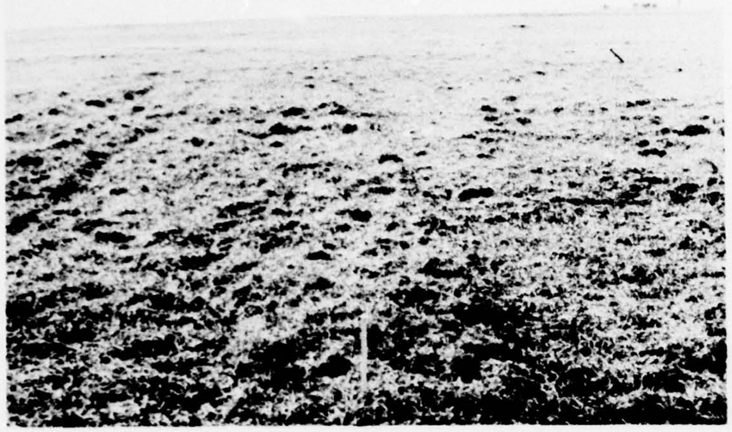
Station 15, looking forward. Map code $\frac{M2,\ U4}{4,\ 4}$
Heavy displacement of moss carpet.

Station 16, looking forward. Map code $\frac{M4,\ U4}{4,\ 7}$

Continuous displacement of moss and squashed hummocks.

Station 15, looking back.

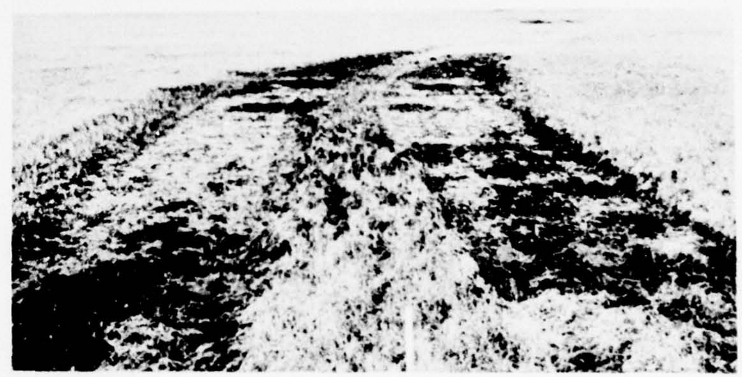
Station 16, looking back.



Station 17, looking forward. Map Code $\frac{U3}{2,\ 9}$

Station 18, looking forward. Map code $\frac{M4,\ U4}{4,\ 7}$

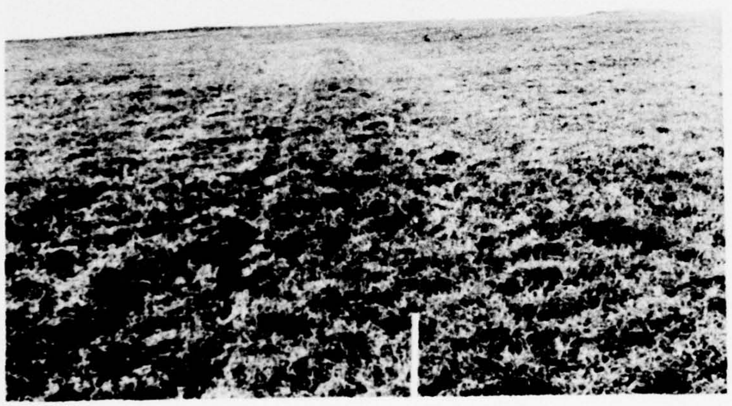
Station 17, looking back.



Station 18, looking back

Station 19, looking forward. Map code $\frac{U3}{2,\ 9}$

Station 20, looking forward. Map code $\frac{B2}{1,\ 8,\ 2}$



Station 19, looking back.

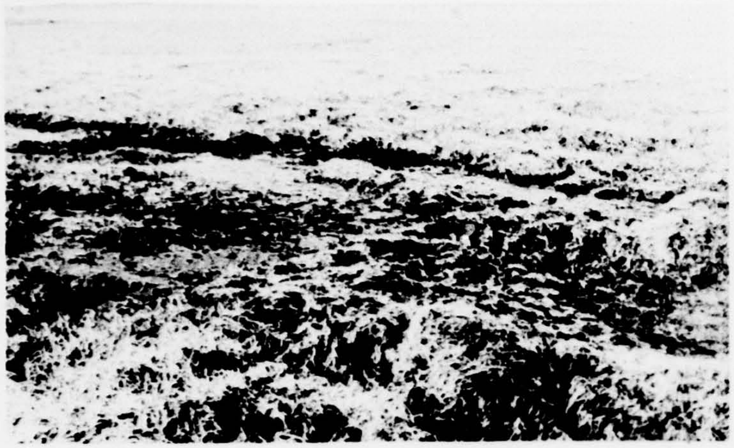
Station 20, looking back.

Station 21, looking forward. Map code $\frac{U3}{2,\ 9}$

Station 22, looking forward.

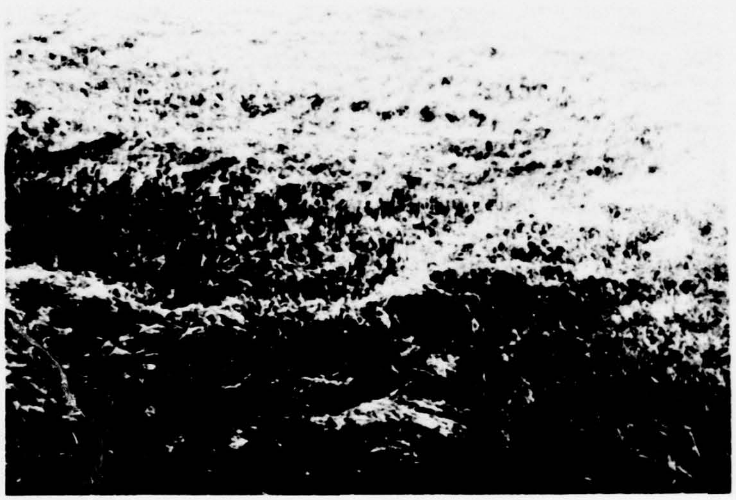
Station 21, looking back.

Station 22, looking back.



Station 22, damage to aligned hummock and displaced moss.

Station 24, looking forward. Map code $\frac{U3}{2,\ 9}$



Station 22, close-up of displaced moss carpet.

Station 24, looking back.

Station 25 (Multiple Pass Lane No. 1) after 30 passes. Map code $\frac{\text{B1}}{\text{1. 8. 3}}$

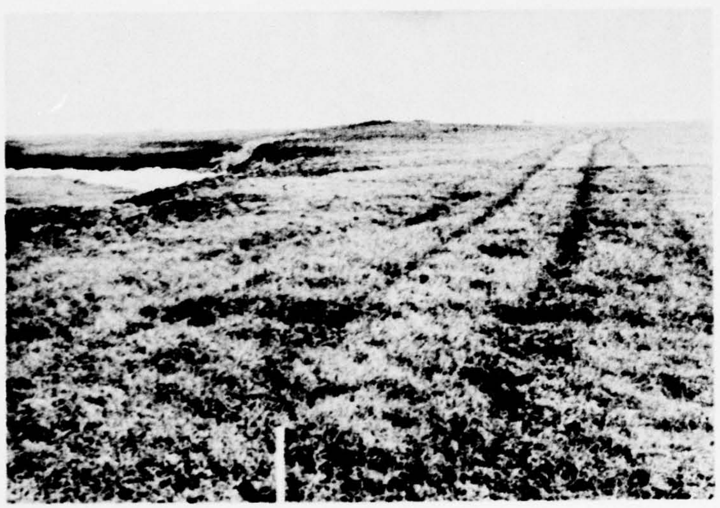
Station 27 (Multiple Pass Lane No. 3) after 30 passes. Map code $\frac{\text{M2, U3, B3}}{\text{3. 4}}$

Station 25, after 30 passes.

Station 27, impacted frost boil after 30 passes.

Station 31, looking forward. Map code $\frac{U3,\ 4}{3,\ 4}$

Station 32, looking forward. Map code $\frac{B1,\ U3}{2,\ 1}$



Station 31, looking back.

Station 32, looking back.

APPENDIX B

Soil Impact (Immediate Compression)

The impact of a Rolligon making a single pass across a number of different soils was evaluated from the standpoint of compression of the near-surface organic or organo-mineral soil horizon (Table B-1). The amount of compression and the recovery of the surface is an index of the resiliency of the surface (shear strength) to the type of stress applied at a given point in time and thus under a given set of physical conditions of the soils.

A number of measurements were made of the compression within each soil-landform unit (Figure 3), in the following manner. A ruler was placed at the interface of the tire track and the adjacent unaffected tundra surface (i.e., the surface at the base of the vegetation). Compression was measured to the nearest 1.25 cm (½ in). The measurements were integrated for a given unit and the impact for the unit assigned to one of four categories as follows:

a.	No compression		rating 0
b.	Slight compression	(1.3 - 2.5 cm)	rating 1
c.	Moderate compression	(2.5 - 7.6 cm)	rating 2
d.	Severe compression	(>7.6 cm)	rating 3

In polygonized landform units separate ratings were given for polygon rims and for polygon centers.

The field test indicated that the impact categories were reasonable even for multipass traffic.

The compression rating was conducted independently of the vegetation impact study and thus in this experiment should not be compared with, for example, values for compression below water surface (Table 2). Future tests will permit such comparisons.

Table B-1. Soil surface horizon compression due to Rolligon passage, and visual impact after 60 days.

Station	Map† Unit	Immediate Compression	Visual impact after 60 days
1	6	3	3
2	2	1	2
3	3	1	2
4	4	R=3* C=1*	R=3 C=3
5	4	1	2
6	3	0	2
7	1	0	2
8	2	0	1
9	4	1	1
10	3	1	2
11	32	R=3 C=1	3
12	3	R=2 C=1	3
13	3	1	1
14	3	R=3 C=1	2
15	4	R=2 C=1	1
16	4	R=2 C=1	2
17	2	0	1
18	4	R=2 C=1	2
19	2	1	1
20	1	0	1
21	2	1	2
22	4	2	2
23	2	0	1
24	2	1	1
25	1	1(2)**	--(3)**
27	3	(3)	(3)
31	3	(1)	(2)
32	2	(1)	(2)

† Only the soil character--first number in the denominator of the map unit fraction is used--see Figure 3.

* R = rim element of polygon.
C = center element of polygon.

** (2) rating after 30 passes of Rolligon.

Visual Impact After 60 Days

Approximately two months after the experiment was completed a short period of time was available to reexamine the test lane. Although no exact measurements could be conducted it was possible to evaluate each soil-vegetation-landform unit with respect to overall residual signs of impact (Table B-1). The criteria used are as follows:

a.	Complete recovery - no visible clues	rating 1
b.	Nearly complete recovery - some visible clues	rating 2
c.	Moderate recovery - many visible clues	rating 3
d.	Slight recovery - essentially original impact condition	rating 4

In Table B-2 an attempt is made to summarize the compression and visual impact ratings by soil type and to develop a single index value for each soil. This is done with full realization of the few data points, the subjectivity of the evaluation and the weighting factor inherent in the distribution of the soil-landform units covered. This last point is, however, not nearly so important as it might be. Soil 6 (Appendix A, Station 1) has only one observation and the most severe rating in both categories. However, it is one of the most homogeneous (with respect to physical characteristics) soils in the Prudhoe area, and it is unlikely that the ratings would change even if the number of data points were greatly increased. Soils 2, 3, and 4, however, are quite heterogeneous with respect to their physical properties and require a large number of data points to fully define their reaction to impact.

Table B-2. Impact indices for immediate compression and 60 day visual impact for each soil type traversed.

Soil	Immediate Compression	60 day visual impact
6	3.0	3.0
2	0.6	1.3
3	1.6	2.1
4	1.9	1.9
1	0.3	1.3

Index values were derived by summing the impact values and dividing by the number of observations. Thirty pass tests are not included.